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Seven Years' Observation of CH4 from AIRS and some comparison between NOAA IASI and AIRS CH4 Products

Xiaozhen (Shawn) Xiong, Chris Barnet, Mitch Goldberg

Eric Maddy, Antonia Gambacorta, Thomas. S. King, Jennifer Wei, Xingpin Liu, Fengying Sun

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Outline

- **As an invited author to present the paper**
  - ✓ Methane plume over south Asia during the monsoon season: satellite observation and model simulation (ACP, 2009)

- **Another paper** published two weeks ago in JGR-A
  - ✓ Mid-upper tropospheric (CH4) in the High Northern Hemisphere (HNH)

- **A few other activities:**
  - ✓ **Validation of IASI CH4 products and comparison of AIRS and IASI CH4;**
  - ✓ **Comparison of AIRS CH4 with GOSAT CH4;**
  - ✓ **Synergy use of AIRS and ground-based FTS measurements from TCCON and NDACC networks to investigate recent CH4 trend (a paper is under reviewed by co-authors).**
  - ✓ **CH4 session in AGU Fall meeting, 2010**

- **Summary**

Atmos. Chem. Phys., 9, 783–794, 2009
www.atmos-chem-phys.net/9/783/2009/

Atmospheric Chemistry and Physics

Methane plume over south Asia during the monsoon season: satellite observation and model simulation

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Abstract. Satellite retrievals of methane (CH_4) using the Atmospheric Infrared Sounder (AIRS) on the EOS/Aqua platform from 2003–2007 show a strong, plume-like enhancement of CH_4 in the middle to upper troposphere over South Asia during July, August and September, with the maximum occurring in early September. Simulations using the global tracer model version 3 (TM3) also show similar seasonal enhancement of CH_4 in the same region. The model results also suggest that this enhancement is associated with transport processes and local surface emissions, thus the observations of tropospheric CH_4 during the monsoon season may be used to constrain the models for a better estimation of Asian CH_4 sources. Further comparisons between the AIRS retrievals and the model simulations suggest a possible overestimate of emissions from rice paddies in Southeast Asia in the scenario with the global emissions from rice of 60 Tg yr^{-1}. Moreover, the observed tropospheric CH_4 enhancement from AIRS provides evidence for the strong transport of atmospheric pollutants from the lower to the upper troposphere in Asia during the monsoon season. The observed rapid disappearance of the local CH_4 maximum in September may provide valuable information for studying the dissipation of the Tibetan anticyclone and the withdrawal of monsoon.

1 Introduction

As the most important greenhouse gas next to carbon dioxide (CO_2), methane (CH_4) is over 20 times more powerful at warming the atmosphere than CO_2 by weight, and plays an important role in atmospheric chemistry (IPCC, 2007). Therefore, understanding the emission sources of CH_4 as well as its transport from the surface to the upper-troposphere/lower-stratosphere is essential for climate change study. This problem is particularly important over Southeast Asia as (1) the rice paddies found in this region are a major, seasonally varying CH_4 emission source (Khalil et al., 1998; Huang et al., 2004), and (2) the deep convection over the Tibetan Plateau (TP) during the monsoon season occurs almost simultaneously with the seasonal high emission. By using satellite observation of carbon monoxide (CO) from the EOS Microwave Limb Sounder (MLS) and water vapor (H_2O) from Tropical Rainfall-Measuring Missing satellite (TRMM), Fu et al. (2006) established that the TP provides the main pathway for cross-tropopause transport of water vapor and polluted air to the global stratosphere. Therefore, the transport of CH_4 over Asia during the monsoon may constitute an important emission pathway transporting CH_4 from lower to the upper atmosphere.

The Tibetan Plateau is located in the southwest of China and is the highest and biggest Plateau in the world, with an area of 2.5 million square kilometers. It is well known that the TP acts as a very strong heat source in summer and has a significant impact on the Asian Summer Monsoon (ASM). The intense convective activity generated at the TP and the large scale vertical motion associated with the ASM transport large amounts of sensible heat, moisture, chemical pollutants, as well as air with low ozone concentration from the near-surface layers to upper layers (Ye and Wu, 1998; and references therein). For example, model simulations (Lawrence et al., 2003; Liu et al, 2003) suggested that deep convection associated with the ASM lifts the boundary layer pollutants from India, Southeast Asia, and southern China into the upper troposphere. A fraction of these can be transported westward by the tropical

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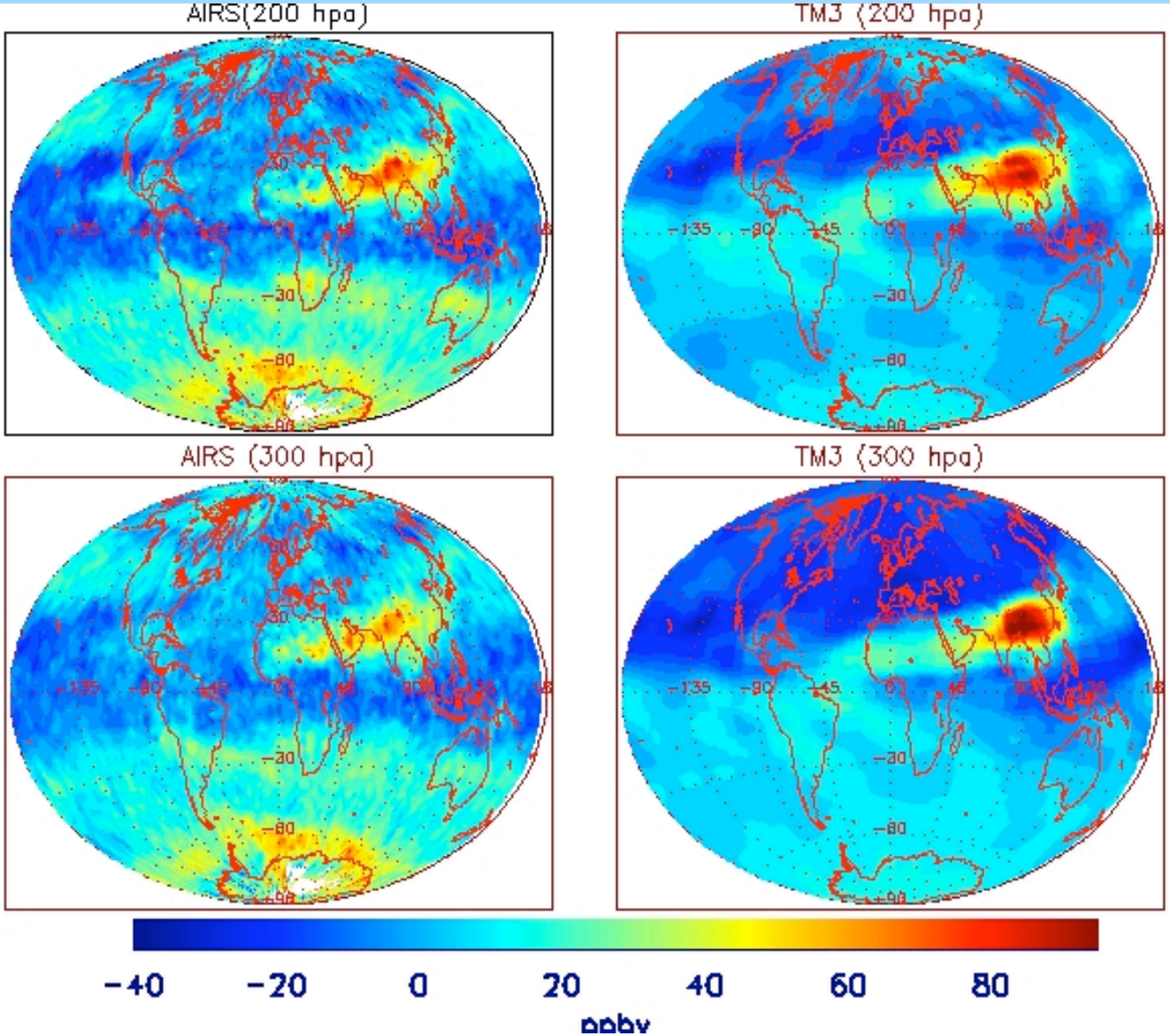
Difference of Methane (Sept-May) from AIRS and Model



enhancement of MUT-CH_4 over the South Asia during JAS, with the maximum occurring in early September

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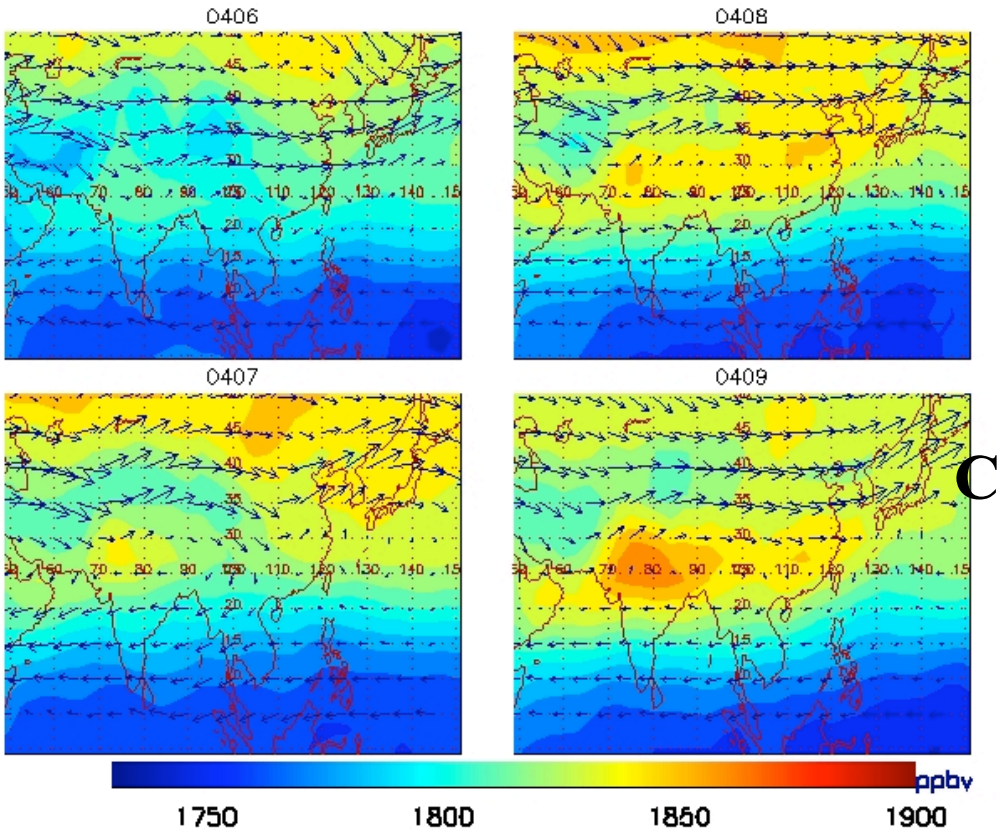
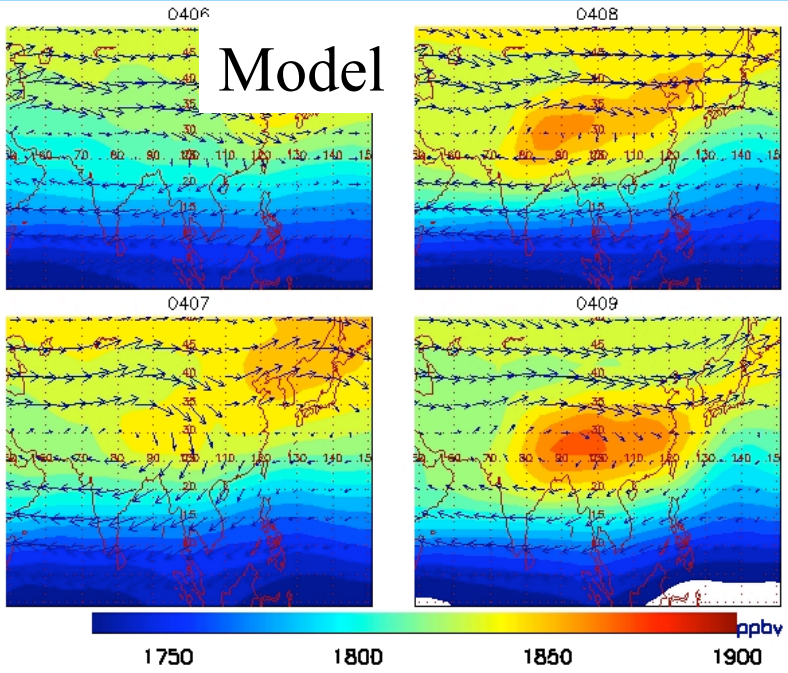
MUT-CH4 over South Asia (JJAS)

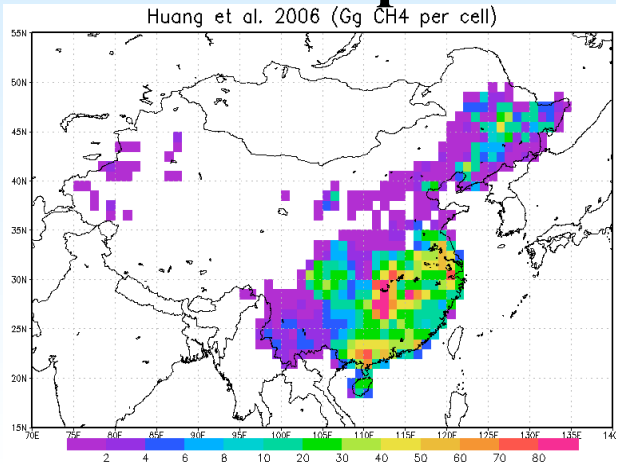
AIRS



Model



CH4 emission from rice paddies



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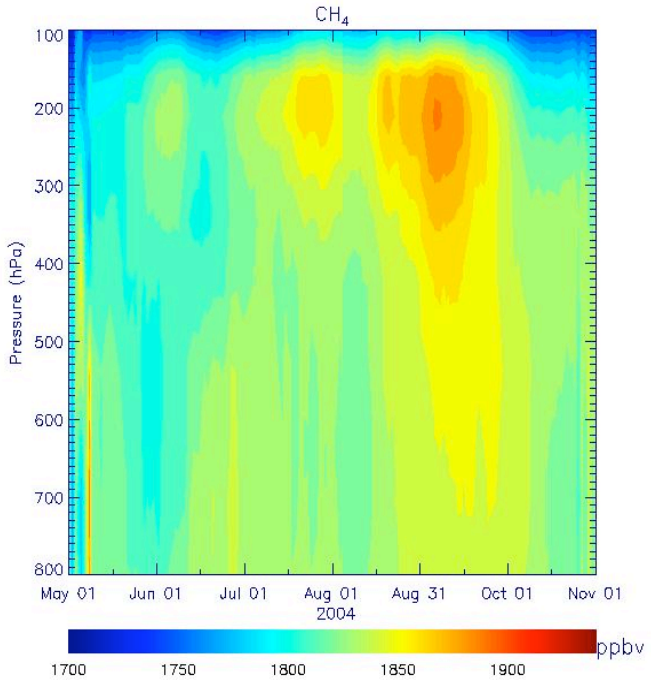
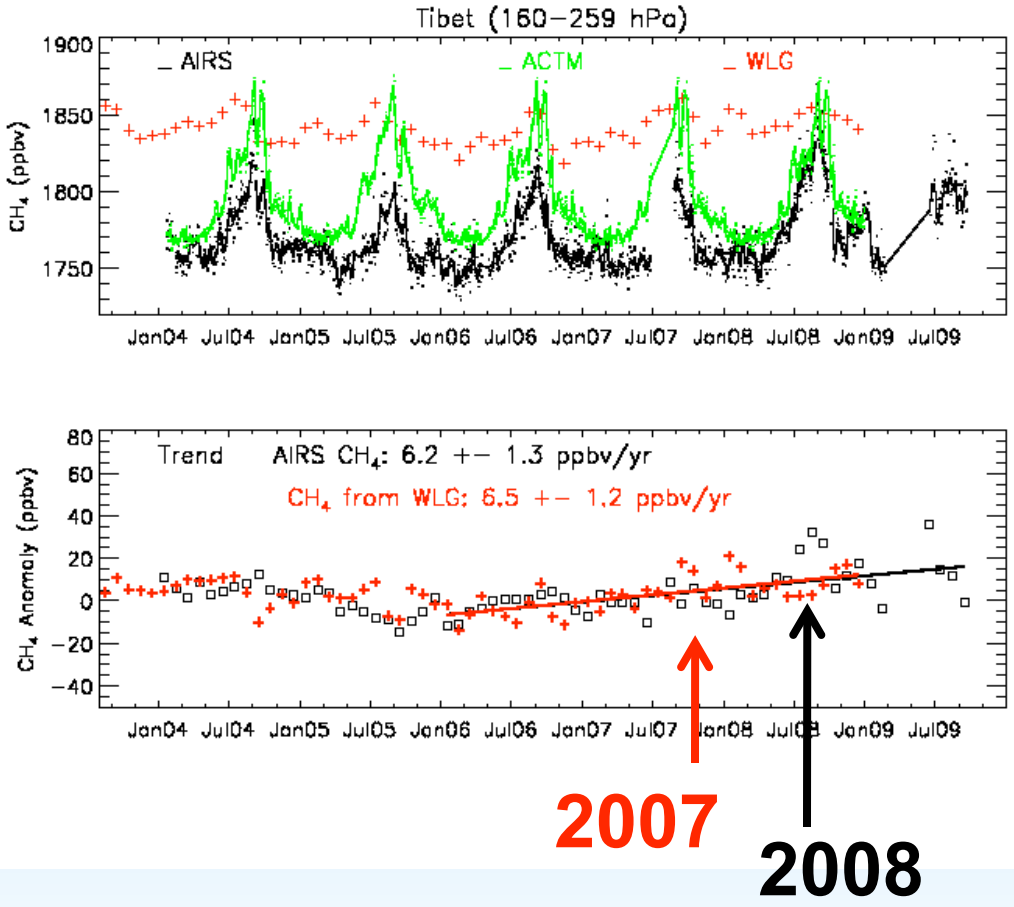
CH4 Plume over South Asia--time series





Sanity-check to the stability of retrieval has been made for quality control

More results in this paper

- **Reasons for this CH4 plume: deep convection and large emission from rice paddies in summer, as well as the impact of Tibetan anticyclone;**

- **Further comparisons with model forward simulations suggest emissions from rice paddies in Southeast Asia towards the lower range, i.e. 31 (~25-120)Tg yr^{-1}.**

- **The observed rapid disappearance of the local CH_4 maximum in September may provide valuable information for studying the dissipation of the Tibetan anticyclone and the withdrawal of monsoon.**

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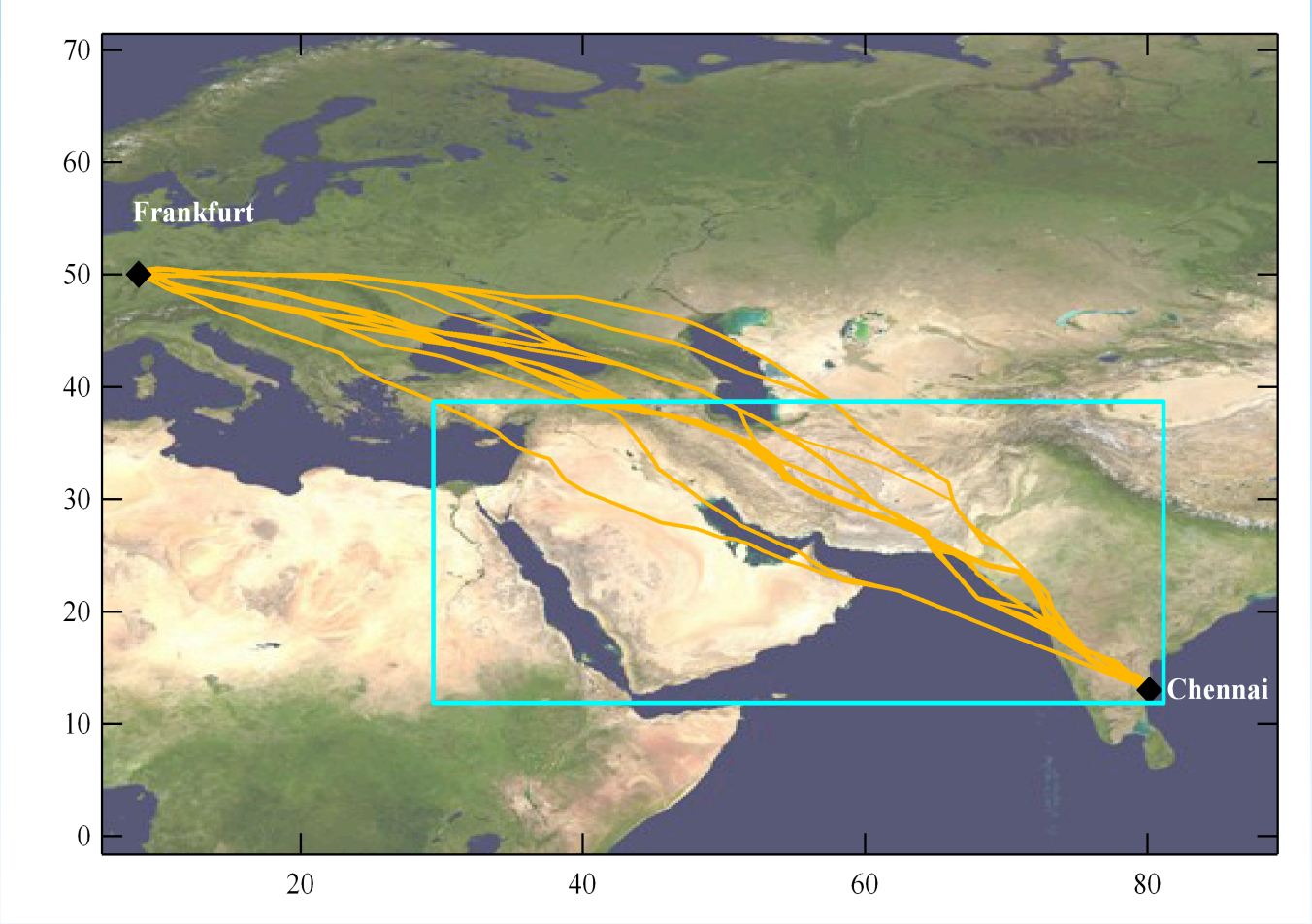
More encouraging evidence is from CARIBIC aircraft measurements



IASI observations confirmed our results (see A.Razavi et al., 2009)

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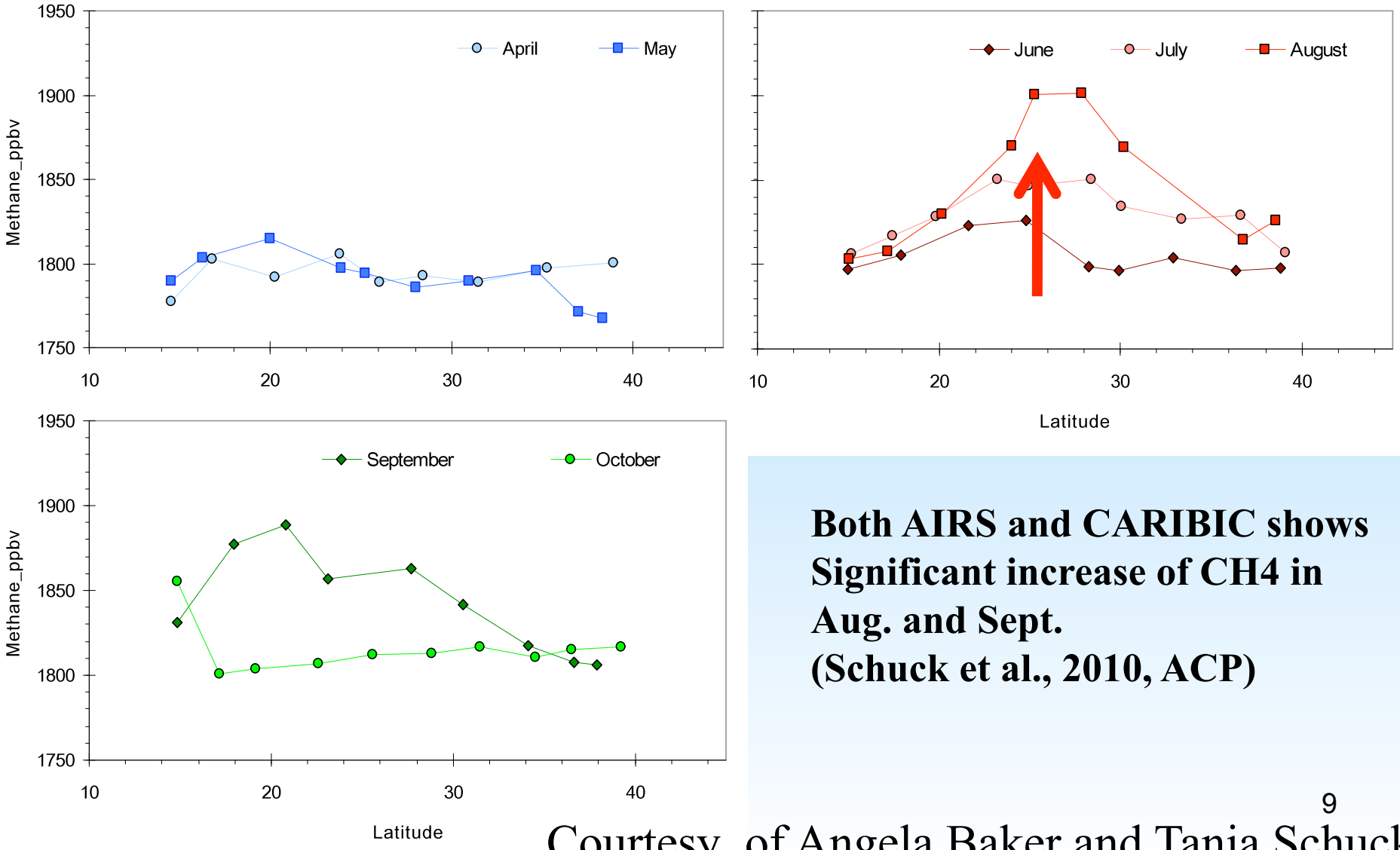
CARIBIC Methane



Both AIRS and CARIBIC shows Significant increase of CH4 in Aug. and Sept.
(Schuck et al., 2010, ACP)

Courtesy of Angela Baker and Tanja Schuck

JGR Journal of Geophysical Research Atmospheres

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 115, D19309, 15 PP., 2010
doi:10.1029/2009JD013796

Mid-upper tropospheric methane in the high Northern Hemisphere: Spaceborne observations by AIRS, aircraft measurements, and model simulations

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Spaceborne measurements by the Atmospheric Infrared Sounder (AIRS) on the EOS/Aqua satellite provide a global view of the methane (CH_4) distribution in the mid-upper troposphere (MUT-CH_4). The focus of this study is to examine the spatiotemporal variation of MUT-CH_4 in the high Northern Hemisphere (HNH) using AIRS retrievals, aircraft measurements, and simulations from a forward chemistry-transport model (i.e., ACTM). Data from 2004 and 2005 focusing over two regions (Alaska and Siberia) are analyzed. An important feature in the seasonal variation of CH_4 we found is the summer increase of MUT-CH_4, which is nearly opposite to the summer minimum of CH_4 in the marine boundary layer (MBL). This study also demonstrated an apparent increase of CH_4 over

Keywords
- methane
- atmosphere
- AIRS

Index Terms
- Atmospheric Composition and Structure: Troposphere: composition and chemistry
- Biogeosciences: Trace gases
- Biogeosciences: Remote sensing
- Biogeosciences: Modeling

one major concern of CH4 study is that changing climate has the potential to dramatically increase CH_4 emissions from thawing permafrost and from Arctic hydrates

--- a positive feedback

- Permafrost thawing
- (~1/4 of areas underlain by permafrost)
- Fire disturbance increase (~1% yr^{-1})

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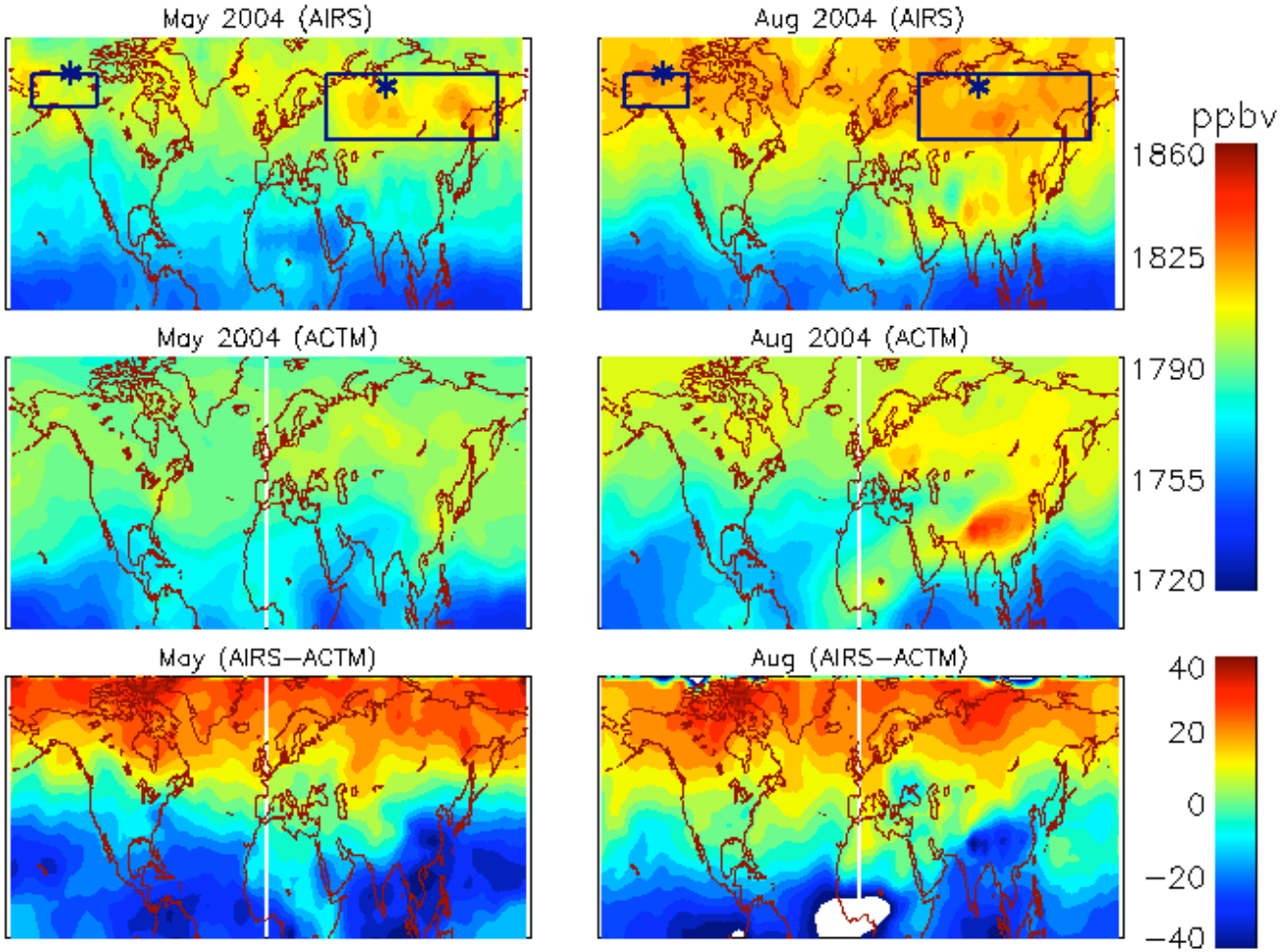
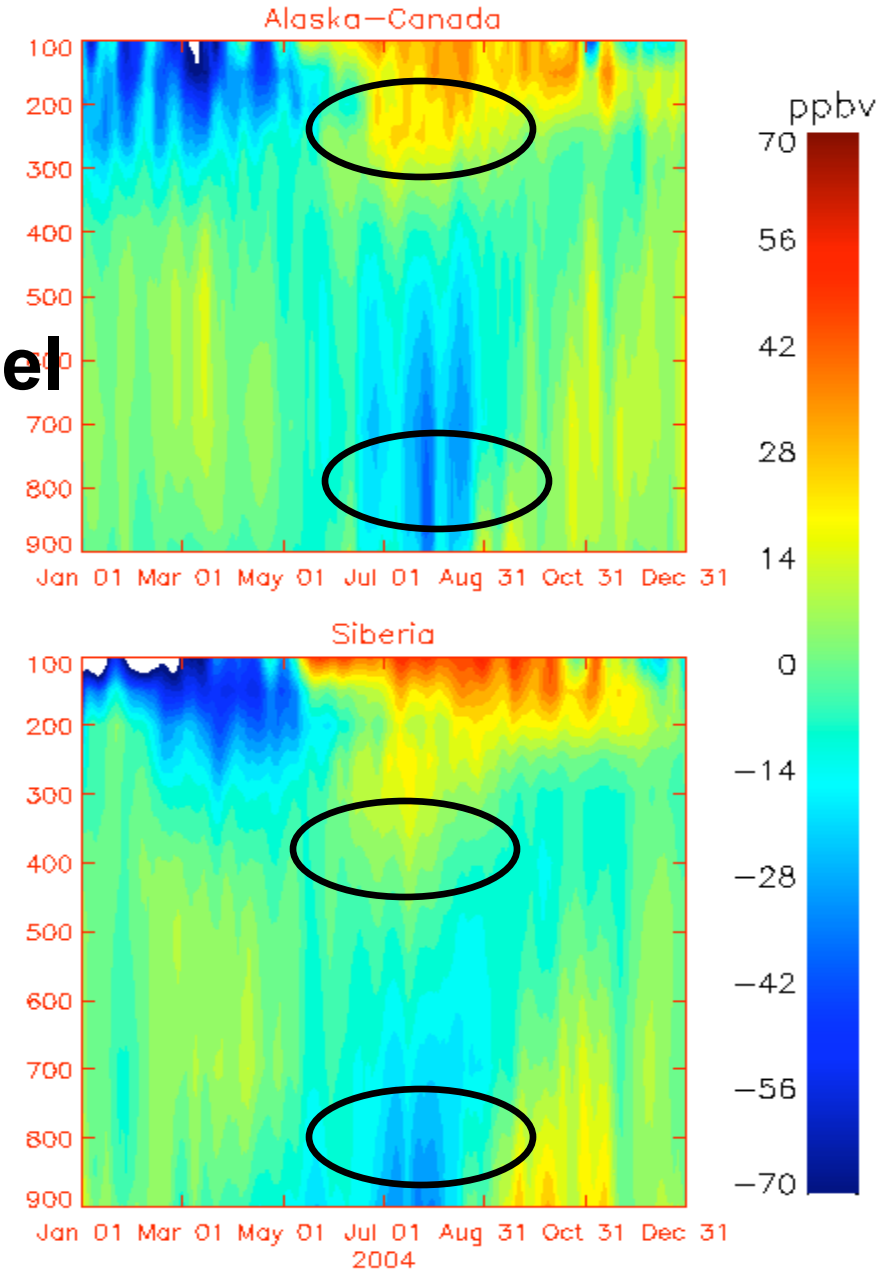
CH4 increase from May and August in the Arctic

AIRS

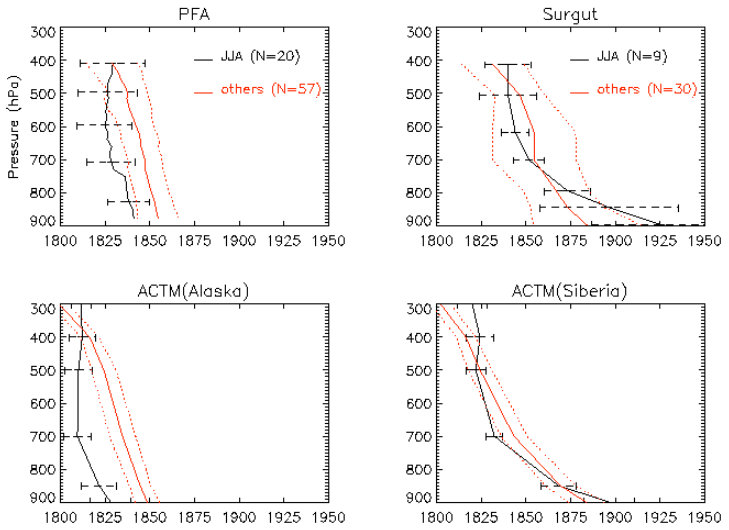
Model



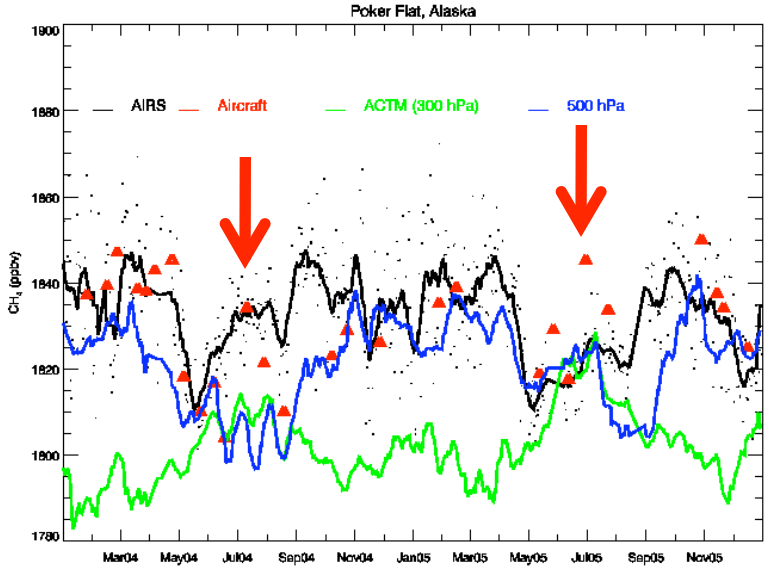
Model

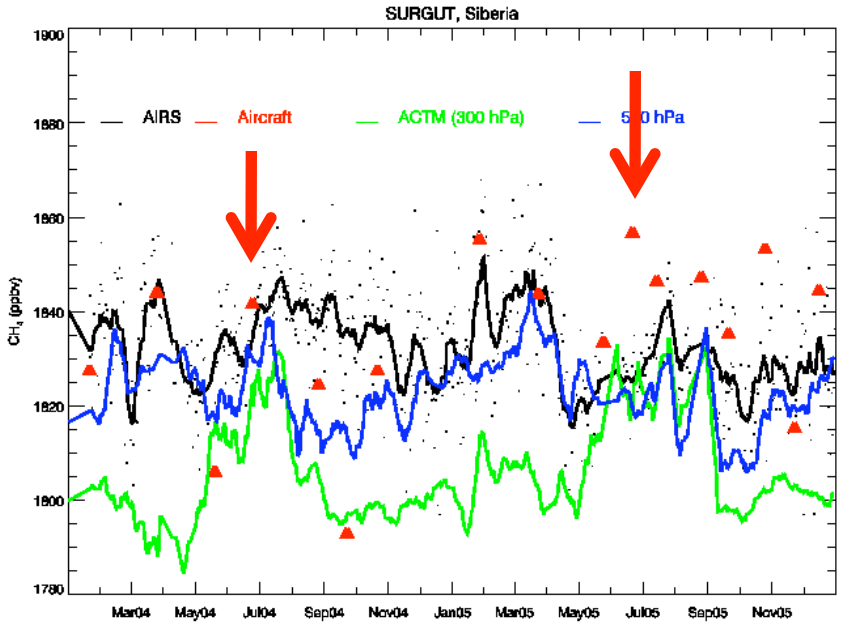


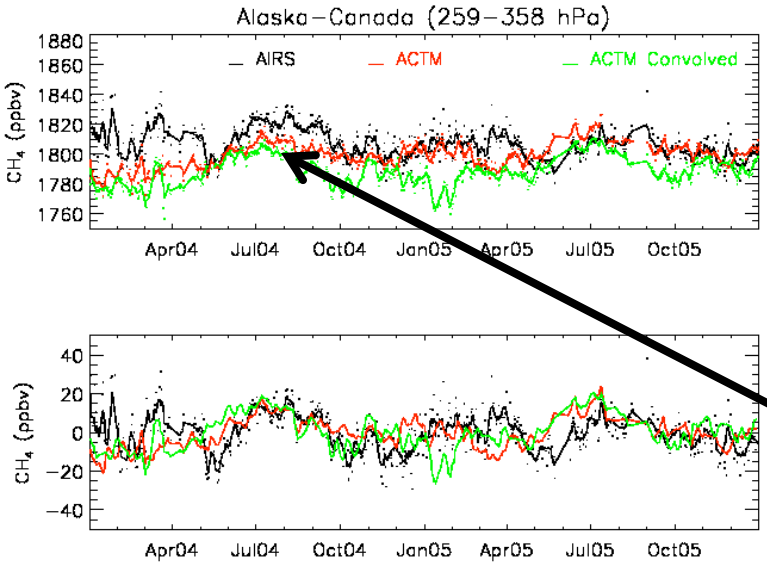
What we found is *the summer increase of MUT-CH_4*, and this seasonal cycle is nearly opposite to the summer minimum of CH_4 in the marine boundary layer (MBL).



Aircraft







Black is AIRS data

red is model results

apparent increase associated with Alaska Fire in 2004

Other Activities

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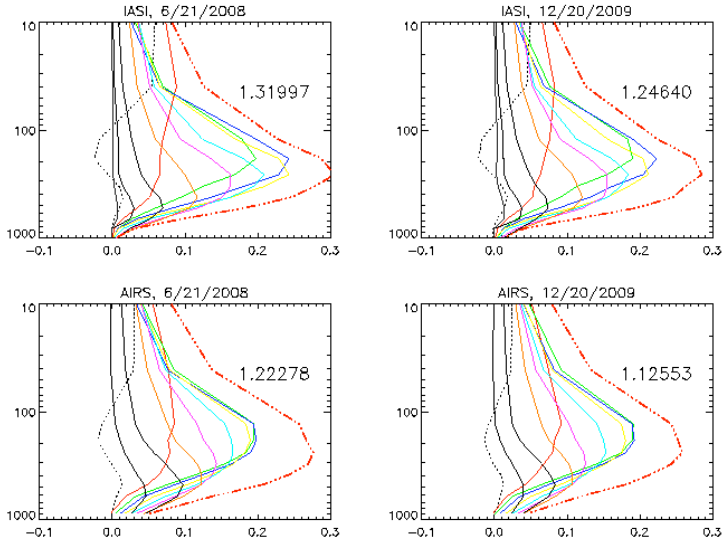
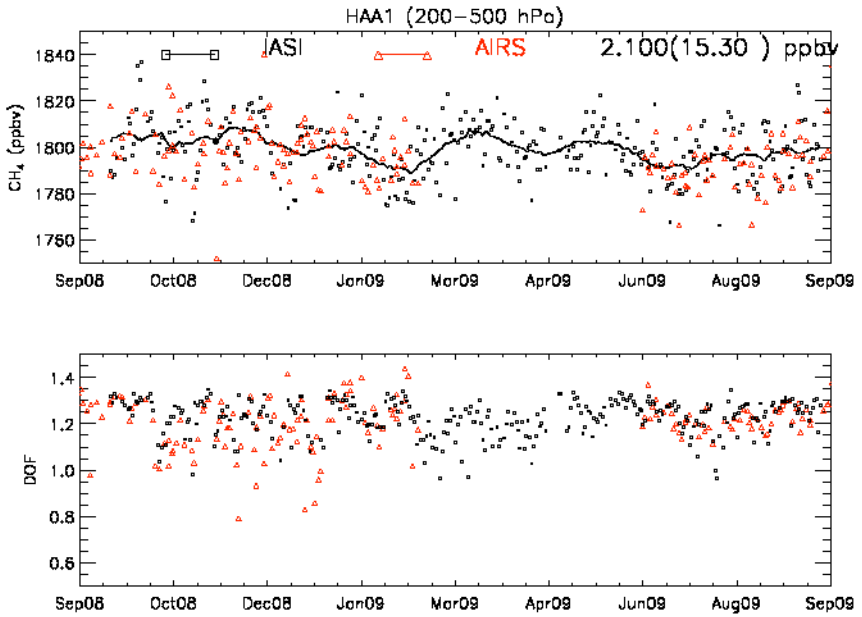
(1) AIRS vs IASI - tropics

IASI has better channels for CH4 retrieval than AIRS

Hawaii





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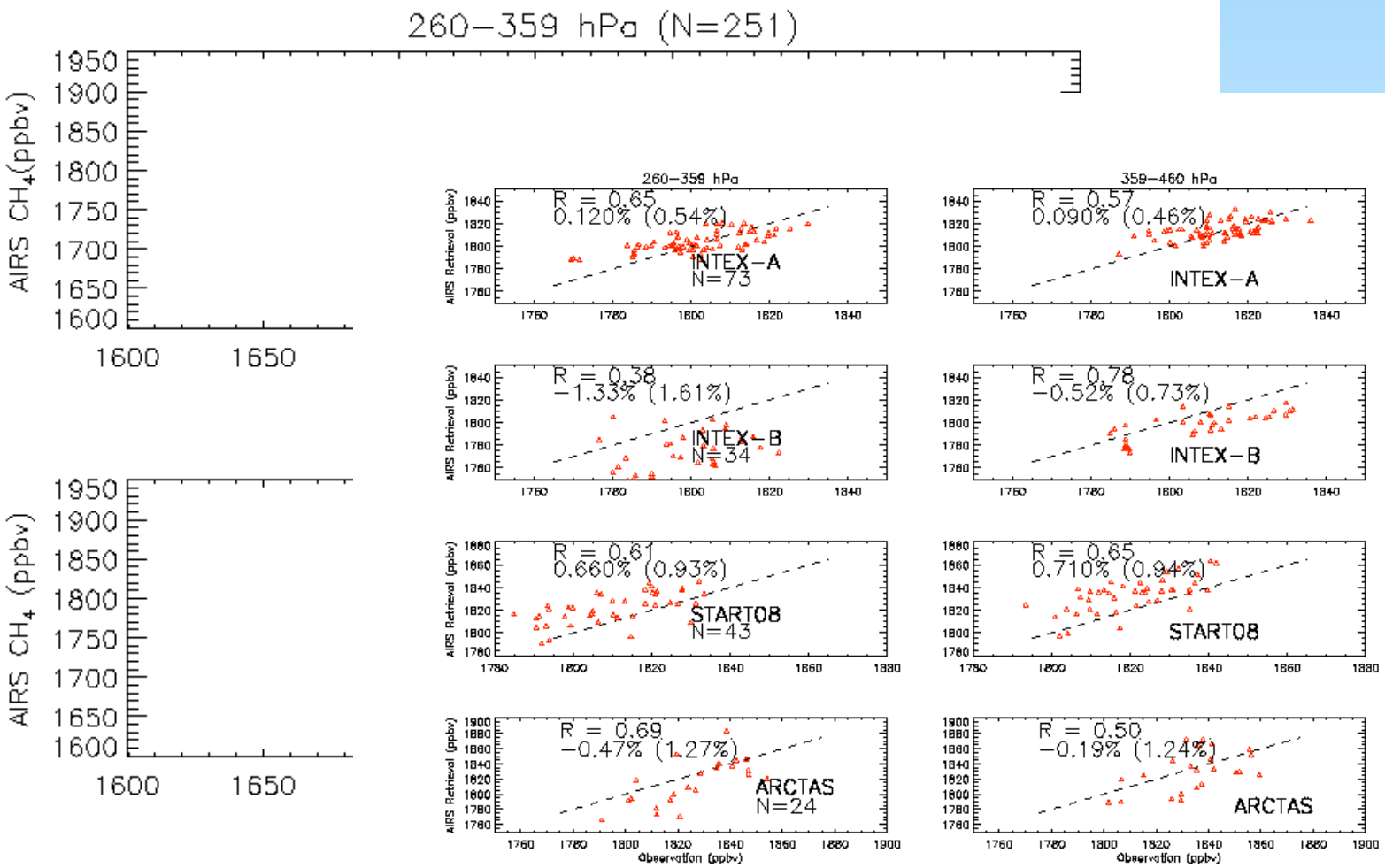
Validation of IASI products (~1.6%)



AIRS

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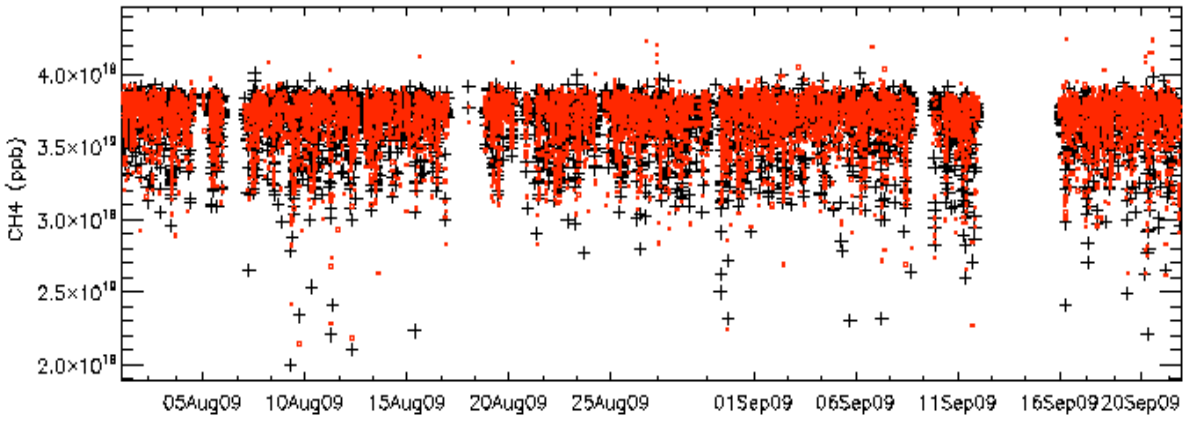
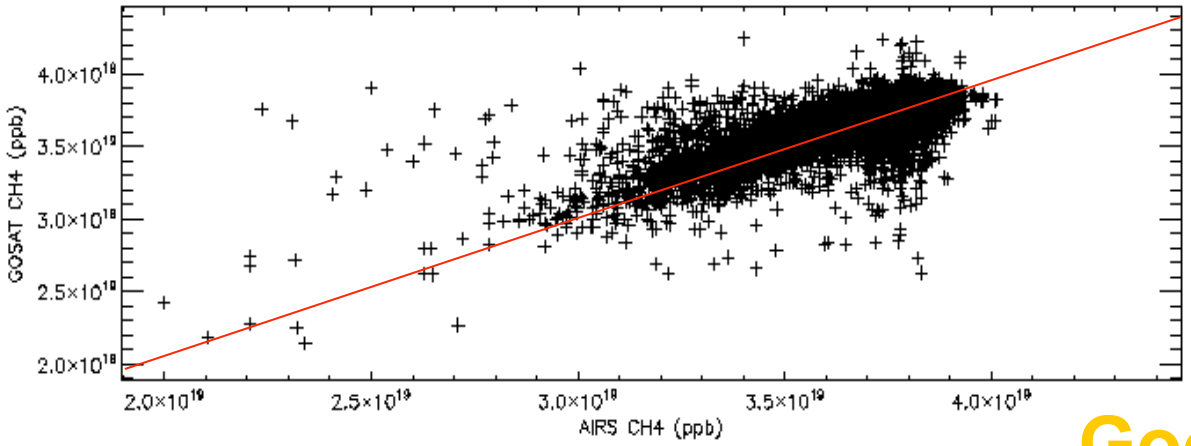
(2) CH4 from AIRS vs GOSAT (total Column)





Good agreement !

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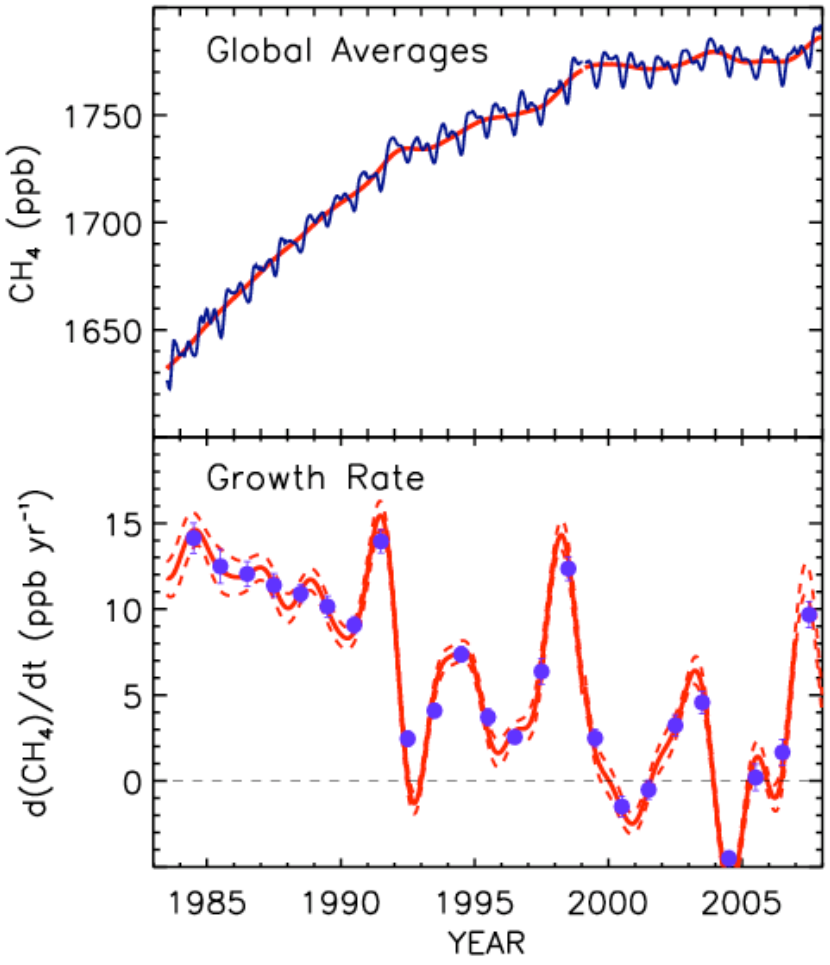
(3) Synergy Use of AIRS, FTS-NIR and FTS-MIR Measurements to explore CH4 Increase in 2007-2008



Courtesy of Ed Dlugokencky

- Initiated in Feb, 2010;
- 11 ground FTS sites in different countries are involved;
- One major finding is the increase of MUT-CH4 occurred since 2008 (see slide 6), which is about 1 year delay than CH4 in surface (a paper is under reviewed by co-authors)
- CH4 decrease in 2010 (from AIRS, reason is not known !)

in 2010 AGU Fall Meeting:

Session GC37: Monitoring and Mitigation of Methane Clathrate Destabilization to Avoid Accelerated Global Warming

Conveners: Robert K. Vincent, Xiaozhen Xiong

X. Xiong, C. Barnet et al., **Space-borne Observation of CH4 using IASI and AIRS at NOAA**

J.Tang, Q. Zhuang and X. Xiong, 2010, **4D-Var inversion of atmospheric methane fluxes by assimilating SCIAMACHY and AIRS satellite retrievals**

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Summary

1. AIRS first observed methane Plume in south Asia, which shed light on the emission in south Asia (rice paddies), and might be used as a tracer of Monsoon;
2. CH4 is found to have a summer increase in the HNH, which is nearly opposite to CH4 in MBL-- calls for more attention to the transport of CH4 emitted from permafrost regions in summer;
5. Comparison of AIRS with ground-based FTS measurements supports the recent CH4 trend, but the increase in MUT is about 1 year's delay; 2010 decrease ?
7. IASI has better channels than AIRS for CH4 retrievals, but the accuracies for them are similar;
5. The total column amounts of CH4 from AIRS agree well with GOSAT measurements using NIR, suggesting the value of AIRS in estimating the surface source might be larger than expected.

Thank you !

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List of Publications

Xiong, X., Barnet, C.; Zhuang, Q.; Machida, T.; Sweeney, C.; Patra, P.K., 2010,Mid-upper Tropospheric Methane in the High Northern Hemisphere: Space-borne Observations by AIRS, Aircraft Measurements and Model Simulations, *J. Geophys. Res*., 115, D19309, doi: 10.1029/2009JD013796.

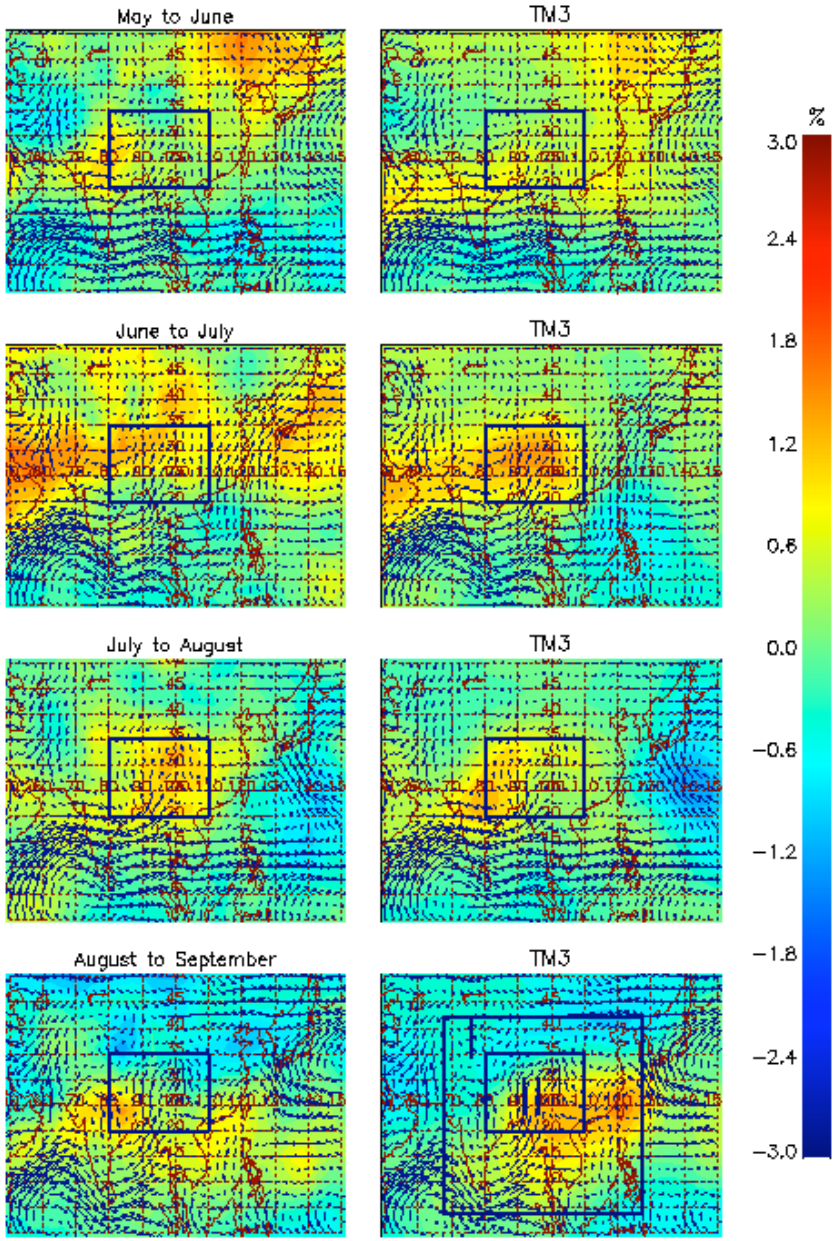
Xiong, X., S. Houweling, J. Wei, E. Maddy, F. Sun, C. D. Barnet, 2009, Methane Plume over South Asia during the Monsoon Season: Satellite Observation and Model Simulation, *Atmos. Chem. Phys.*, 9, 783-794, 2009 .

Xiong, X., C. Barnet, E. Maddy, C. Sweeney, X. Liu, L. Zhou, and M. Goldberg, 2008, Characterization and validation of methane products from the Atmospheric Infrared Sounder (AIRS), *J. Geophys Res*., 113, G00A01, doi:10.1029/2007JG000500.

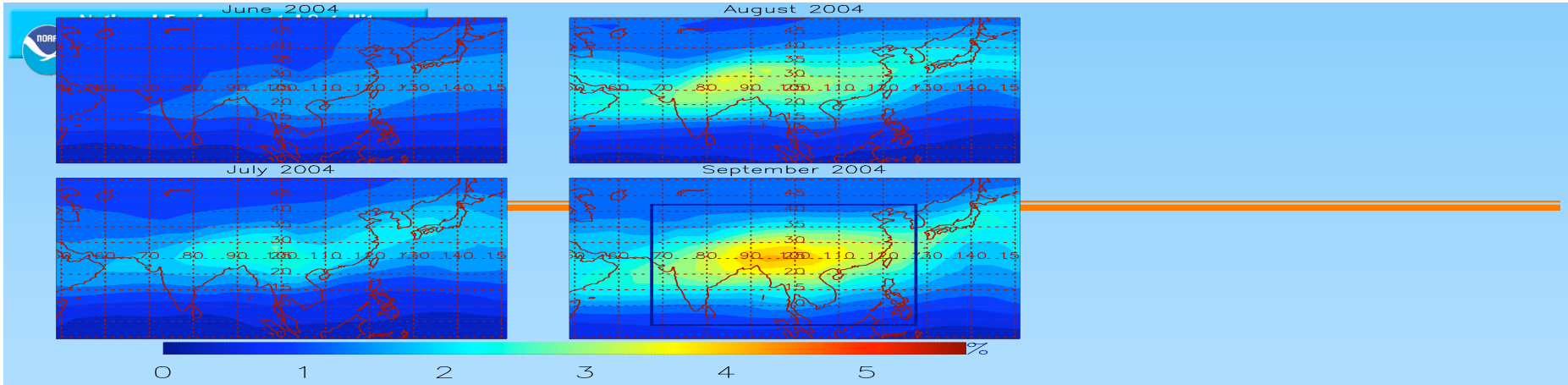
Xiong, X., Barnet, C.D., Maddy, E., Liu, X., and Goldberg, M., 2008. Variation of Atmospheric Methane over the Permafrost Regions from Satellite Observation during 2003 to 2007. *Proceedings of the Ninth International Conference on Permafrost*, Alaska, USA: 1981-1986 pp.

Patra, P. K., Xiong, X., Barnet, C.D., Dlugokencky, E. J., Karin, U., Tsuboi, K., Worthy , D., Validation of CH4 surface emission using forward model transport *Proceedings of the* 18th International Emission Inventory Conference - "Comprehensive Inventories - Leveraging Technology and Resources", Baltimore, USA, April 13-17, 2009

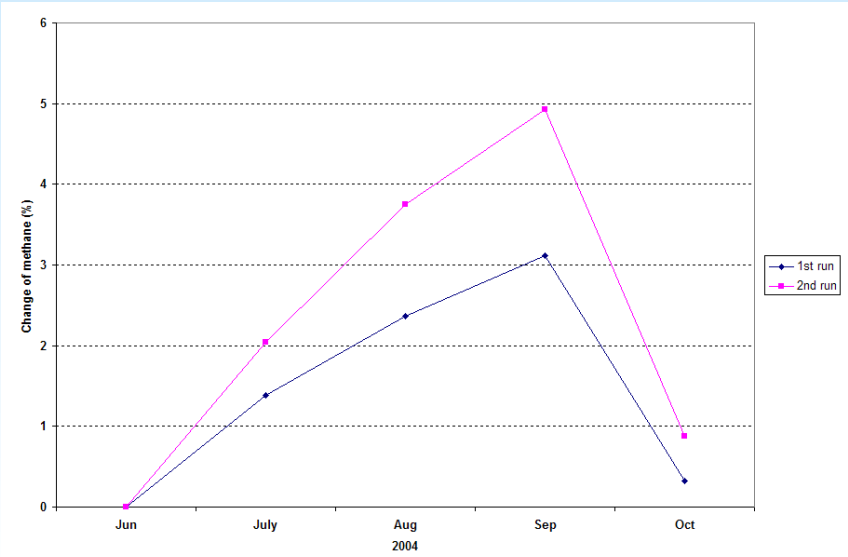
Xiong, X., Barnet, C., Wei, J., Maddy, E., Information-based mid-upper tropospheric methane derived from Atmospheric Infrared Sounder (AIRS) and its validation, Atmospheric Chemistry and Physics Discussions, Volume 9, Issue 4, 2009, pp.16331-16360

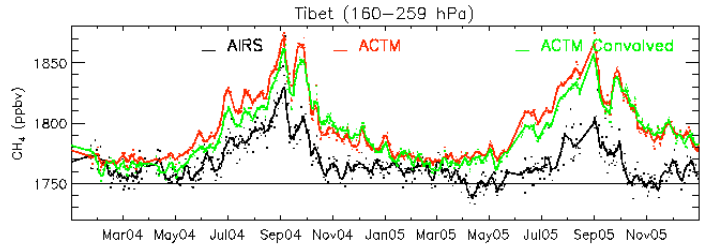


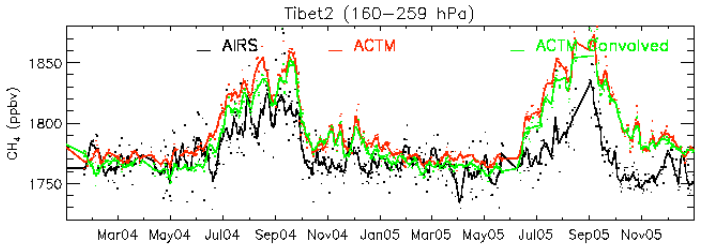
Monthly change of methane at 300 hPa during the monsoon season (June - Sept in Southeast Asia from AIRS observation and its comparison
with model simulation



Model simulated change of methane assuming 50% change of emission




Tibet (160–259 hPa)
AIRS
ACTM
ACTM Convolved
CH4 (ppbv)
1850
1800
1750
Mar04 May04 Jul04 Sep04 Nov04 Jan05 Mar05 May05 Jul05 Sep05 Nov05
80
60
40
20
0
−20
−40
JJA
JJA


Tibet2 (160–259 hPa)
AIRS
ACTM
ACTM Convolved
CH4 (ppbv)
1850
1800
1750
Mar04 May04 Jul04 Sep04 Nov04 Jan05 Mar05 May05 Jul05 Sep05 Nov05
80
60
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−20
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JJA
JJA

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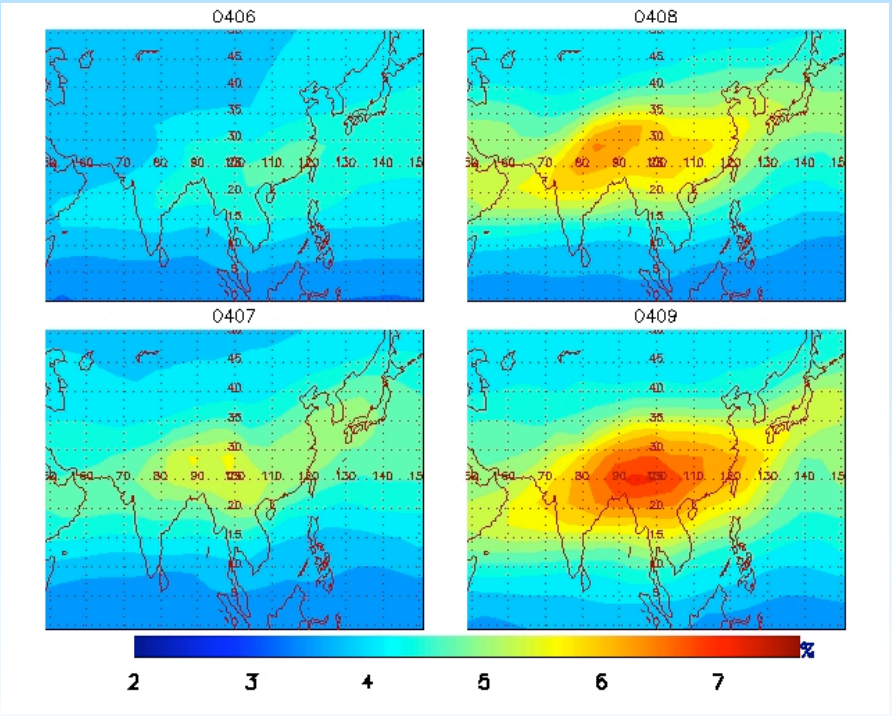
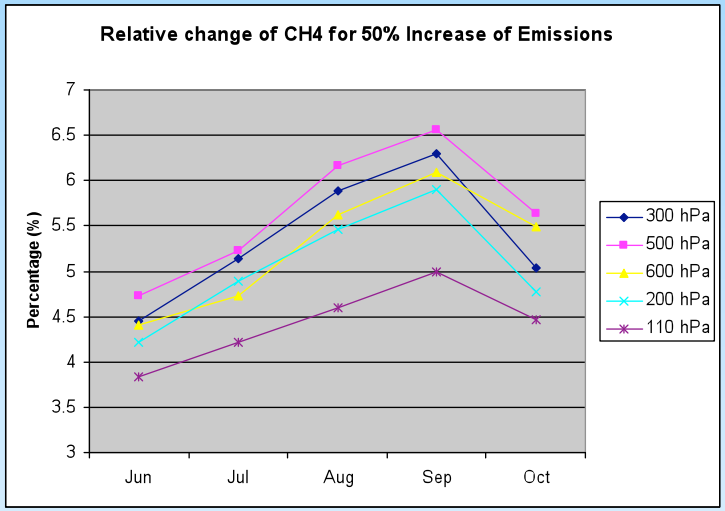
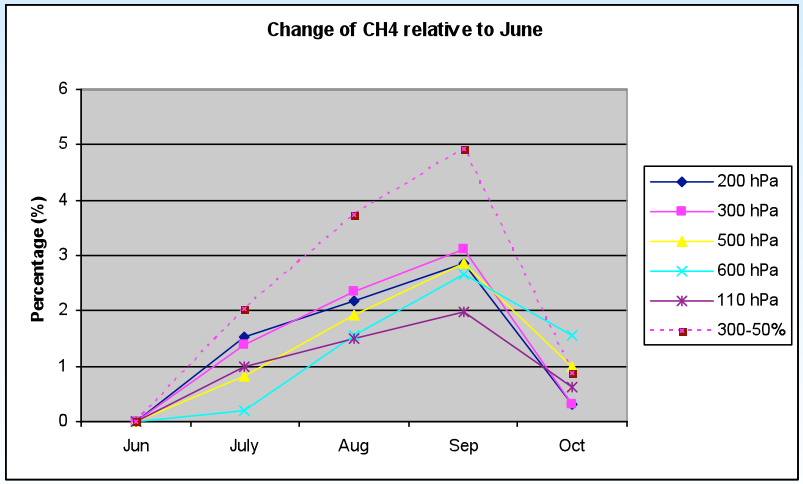
Sensitivity of Tropospheric CH4 to 50% increase of Surface Emissions (TM3)








洲 地 势
1:3500万
350 700 1050公里
Himalaya Mts
Tibetan Plateau

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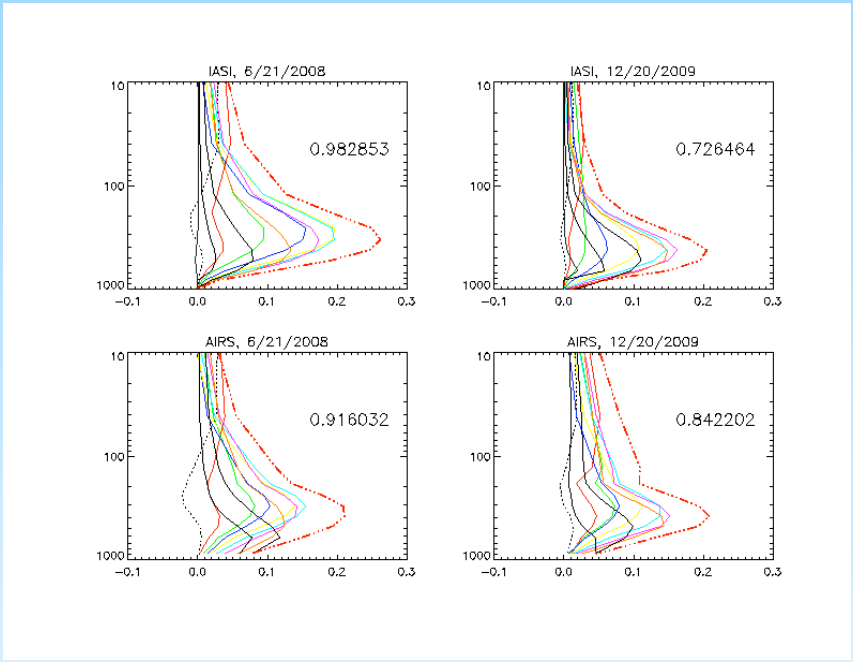
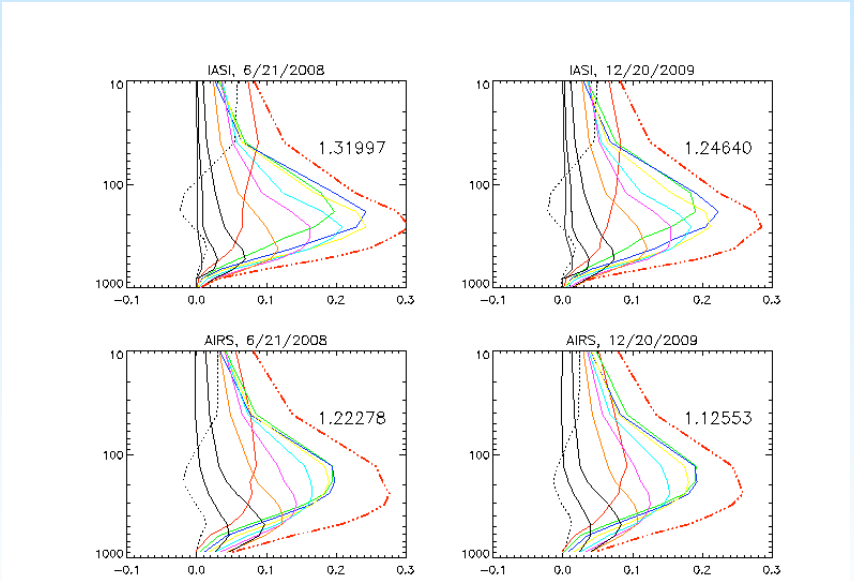
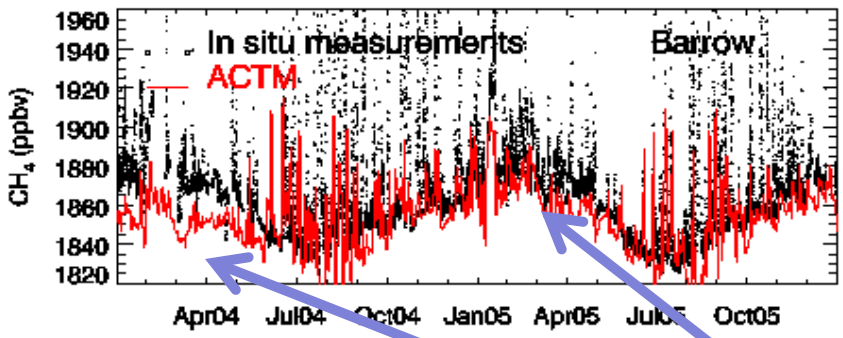
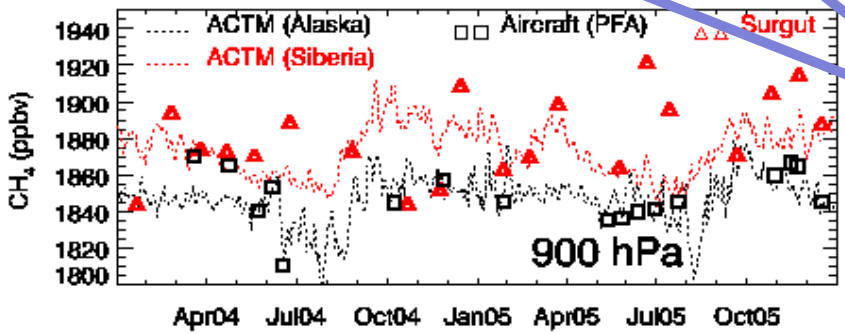
Example of Averaging kernels of IASI in Polar region

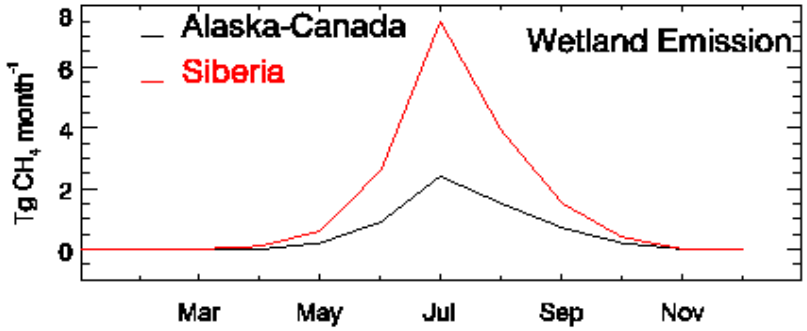


IASI has better CH4 channels Than AIRS









a negative bias of the ACTM simulations in the HNH.